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Stress Isolation Used In MEMS Resonant Pressure Sensor Package

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Abstract

This paper presents a method of stress isolation which was designed to minimize mechanical and thermal stresses to a MEMS (microelectronic-machined systems) resonant pressure sensor package. Finite element modelling (FEM) analysis and experimental verifications are carried out to design the idea of stress isolation. The sensor die is mounted to the metal substrate by fixing the die only at a corner through stacks of small silicon dies with WD3620 epoxy resin. Experimental tests show that adhesion capability of the adhesive used in bonding silicon chips maintains well after thermal treatments, cleaning, handling, bench testing and implantations, and null drift of the sensor due to external mechanical stress is significantly improved, and the temperature drift is less than 0.05%F.S/°C in the temperature range from -40°C to 70°C, reducing a factor of 25 compared with that of the sensors without stress isolation.

Keywords: Stress isolation; FEM analysis; metal substrate; silicon dies;

1. introduction

MEMS mechanical sensors require careful packaging in order to protect the inherently fragile mechanical components and to prevent undesirable external influences. Resonant pressure sensor is of great sensitivity sensitivity to stress and other factors, and offers excellent long-term frequency stability, which means tiny stress induced by the environment will influence its performance. The mechanical interface must isolate the sensor from undesirable external stresses and provide relief from residual

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stresses in the assembly while enabling the desired mechanical effect arising from the measured to be coupled to the sensor [1]. Stress induced by packaging is mainly caused by thermal expansion coefficient (TEC) mismatches among the component materials making up the package, which is usually inevitable [2].

To minimize the stress induced by packaging, we propose a method of stress isolation to the resonant pressure sensor package in this paper. Experiments shows that this low-cost packaging approach provides a good degree of mechanical isolation, and temperatures drift of the sensor is significantly reduced.

2. Experiments

The basic elements of a resonant pressure sensor are four "H" style clamped-clamped boron diffused silicon beams suspended on a silicon square diaphragm by three anchors and a silicon rectangular frame, which are organized symmetrically along the diagonal direction; two of the same side provide differential output [4].

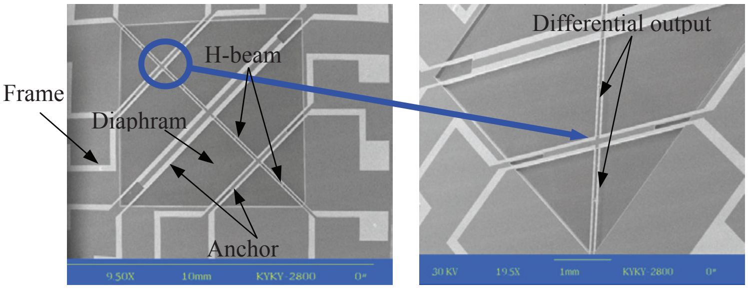
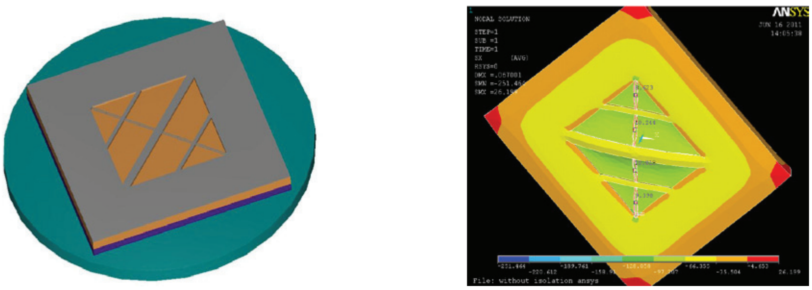


Fig. 1. SEM Photos of resonator pressure sensor

Kovar is chosen as the resonant pressure sensor package for its high reliability. However, the TEC mismatch between the metal substrate and the silicon wafer induces great thermal stresses to the resonator. A widely adopted method to reduce stress is stress isolation. Theoretical analysis, finite element modeling (FEM) analysis, as well as experimental verifications are carried out to investigate the stress isolation.



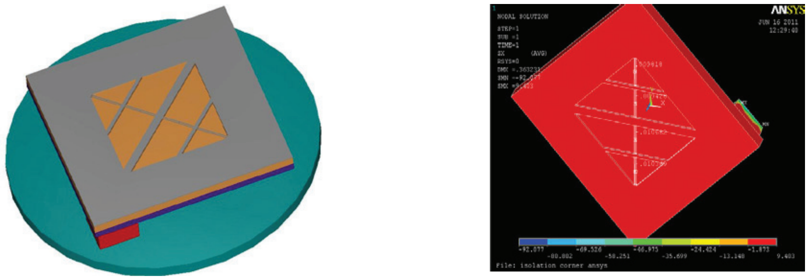
(a) (b)

Fig. 2. (a) Schematic of direct bonding (b) Axial stress(y direction) distribution of at 100°C

The sensor chip is bonded to a supporting silicon wafer by adhesive bonding to form a sealed chamber for a zero-pressure reference. Fig.2 shows the axial stress(y direction) distribution of the sensor structure at 100°C when the supporting silicon wafer is directly placed on the kovar substrate, the thermal stress at the central point of the beam is about 10MPa. Experiments show that the temperature drift is 10 kHz ~15 kHz (7%F.S/°C ~10%F.S/°C) in the temperature range from -40°C to 70°C.

To improve the performance of packaging, we present a method of stress isolation. Stress isolation is usually achieved by setting separation of the sensor chip away from the supporting substrate, making the sensing element separated from the substrate by a small gap. In our design, the isolation is realized by bonding a stack of silicon support chips (2mm×2mm) at a corner of the frame using WD3620 epoxy resin, which provides both vertical and horizontal separation.

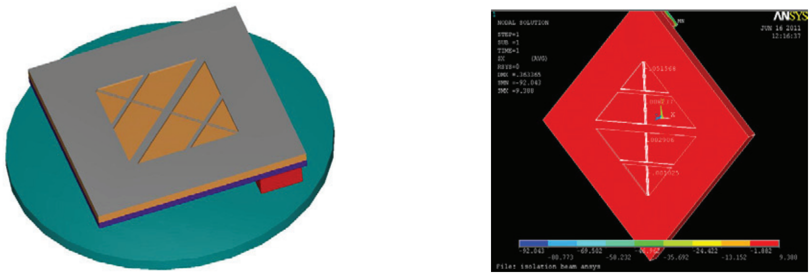
The isolation effect depends on the bonding location of the small support chips. When the small support chips are located at the corner away from the beams, shown in Fig.3(a), FEM simulations give the axial stress(y direction) distribution of the sensor structure at 100°C, as shown in Fig.3(b). The thermal stresses on the central point of each beam are about 0.02MPa， which is 0.2% of that without isolation. Experiments show that the temperature drift is 0.5 kHz ~0.6 kHz (0.07%F.S/°C ~0.08%F.S/°C) in the temperature range from -40°C to 70°C.



(a) (b)

Fig. 3.(a) Schematic of the stress isolation (b) Axial stress(y direction) distribution of at 100°C

Fig.4(a) shows the small support chips are located at the corner near the beams， FEM simulations give the axial stress(y direction) distribution of the sensor structure at 100°C, as shown in Fig.4(b). Thermal stress on the beams far away from the isolation is about 0.01Mpa, which is 0.1% of that without isolation. Experiments show that the temperature drift is 0.3 kHz ~0.5 kHz (0.03%F.S/°C ~0.05%F.S/°C) in the temperature range from -40°C to 70°C. Fig.5 shows the view and the photograph of the stress isolation.



(a) (b)

Fig. 4.(a) Schematic of the stress isolation (b) Axial stress(y direction) distribution of at 100°C

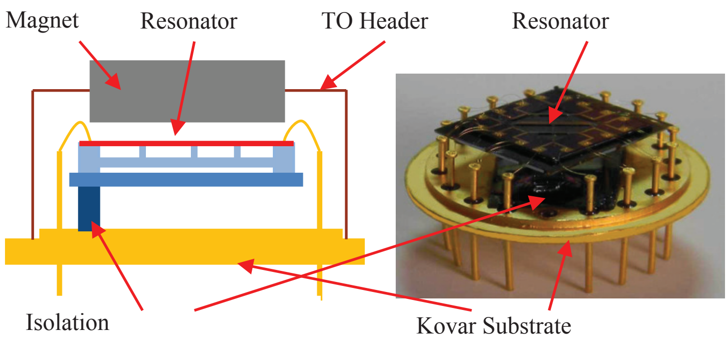


Fig.5. View and Photograph of stress isolation

Fig.6 shows the plot of temperature drifts of the sensors with and without stress isolation. Measured output frequency shift of the pressure sensor associated with the temperature variation at 1atm, the temperature drift of the sensor is less than 0.05% span/℃from -40°C to 70°C, which is 4% of the sensors without stress isolation. FEM analysis shows that the stress transmitted to the beams is only 0.1% of that without isolation, which is not quite according to the experimental results. That is because bonding material between the die and supporting chips adds some stress, but it is too little to affect the function of the sensor.

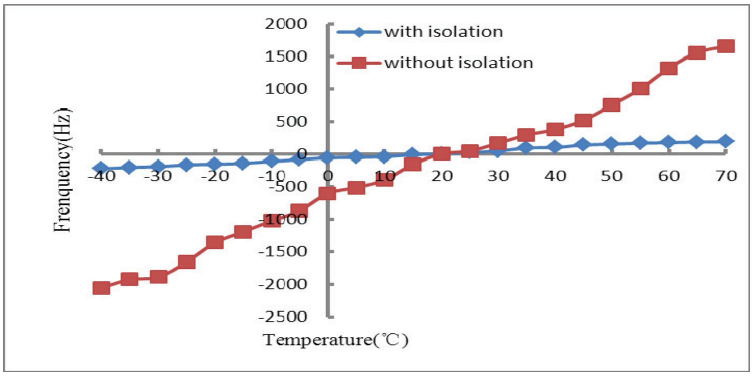


Fig.6. Plot of temperature drifts of the sensors with and without stress isolation at 1atm from -40℃to 70℃

3. Conclusion

We present a novel way of stress isolation used for resonant pressure package by FEM analysis and experimental verifications. The isolation can successfully isolate TEC mismatches among the component materials making up the package, and reduce a factor of 25 compared with that of the sensors without stress isolation. This low cost isolation technique is suitable for traditional metal package and plastic package.

Acknowledgements

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References

[1] C. H. Yun, X. Zhang, V. Kumar, Stress Isolation Structures in MEMS Gyroscope Packages. *ASME2007 InterPACK Conference* 2007;505-508.

[2] Sung Hoon Choa, Reliability of MEMS packaging: vacuum maintenance and packaging induced stress, *Microsyst Technol* 2005;11:1187–1196.

[3] Stephen Beeby, Graham Ensell, Michael Kraft,Neil White, *MEMS Mechanical Sensors 2004*.

[4] Deyong CHEN, Junbo WANG, Yuxin LI，A Novel Laterally Driven Micromachined Resonant Pressure Sensor. *Sensors 2010 Conference* 2010;1727-1730.